3.2 Toxic Chemical Contaminants

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NOAA FISHERIES

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40+ years of toxics research at NWFSC

Focal area: toxic chemical contaminants

- > 80,000 chemicals currently in societal use
- Many enter coastal and ocean habitats via accidental spills, direct discharge, land-based runoff and atmospheric deposition
- A global threat to **protected resources**, seafood safety, healthy habitats, and sustainable fisheries
- A problem that is growing with increasing coastal development, natural resource extraction, severe weather, and shipping
- NMFS will need a national research and assessment capacity for toxics to meet **current and future conservation challenges**

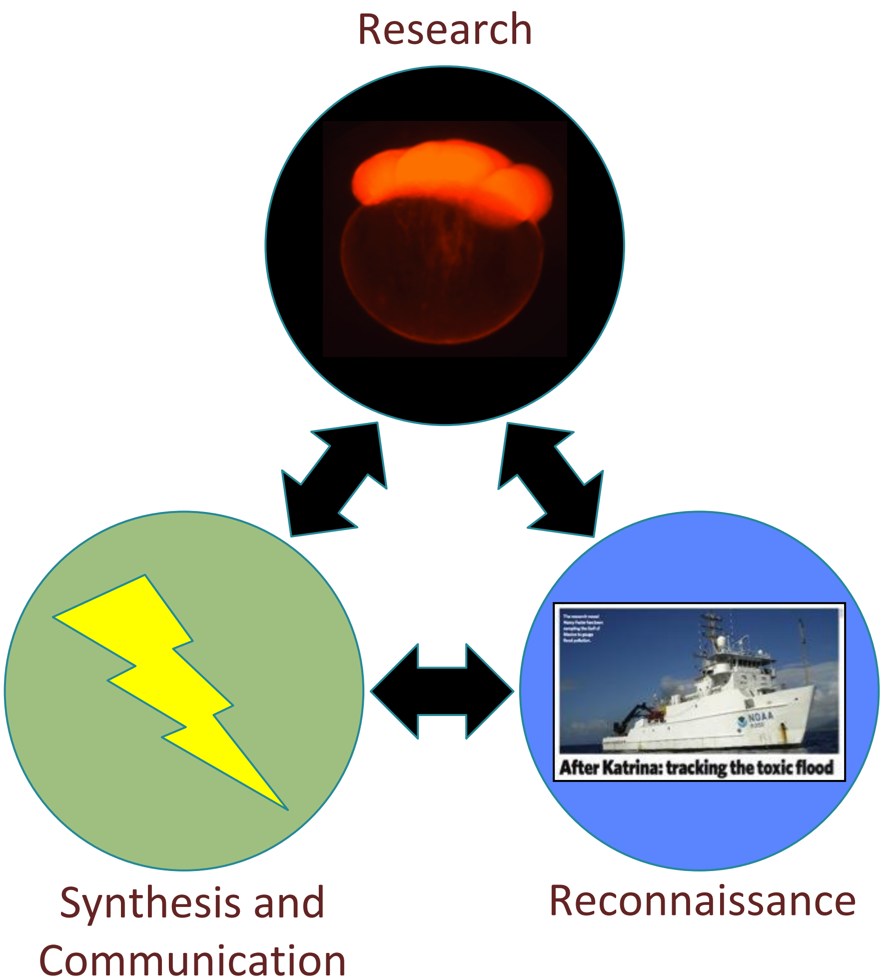
A network of collaboration (FY10-15)

- Alaska Department of Fish & Game
- Bahamas Marine Mammal Survey Org.
- Bodega Marine Laboratory (UC Davis)
- Cascadia Research Collective
- Korea Ocean R&D Institute
- Lower Columbia River Estuary Partnership
- Marine Mammal Center (Sausalito, CA)
- North Slope Borough
- Norway Institute for Marine Research
- Oregon State University
- Provincetown Center for Coastal Studies
- Queen's College (Canada)
- Simon Fraser University (Canada)
- Stanford University
- University of Alaska, Fairbanks
- University of Miami
- University of South Florida
- Univ. St. Andrews, Sea Mammal Unit
- University of California, Berkeley
- University of California, Davis
- University of Texas
- University of Washington
- University of Tromsø (Norway)
- U.S. Fish and Wildlife Service
- U.S. Geological Survey
- Washington State University

- NOAA-F, Alaska & Pacific Islands Fisheries Science Centers
- NOAA-F, Southwest Fisheries Science Center (now WCRO)
- NOAA-F, Southeast Fisheries Science Center
- NOAA-F, Office of Protected Resources

- NOS, Office of Response and Restoration
- NOS, National Centers for Coastal and Ocean Science
- NOS, Coastal Services Center

Ecotoxicology Program core competencies



Research

- ▶ Injury thresholds
- ▶ Toxic mechanisms/pathways
- ▶ Controlled experimental field studies
- ▶ Mixtures and multiple stressors
- ▶ Next generation biomarkers

Reconnaissance

- ▶ Habitat restoration effectiveness
- ▶ Seafood safety/surveillance
- ▶ Environmental status and trends
- ▶ Chemicals of emerging concern
- ▶ Sentinels for ecological/human health

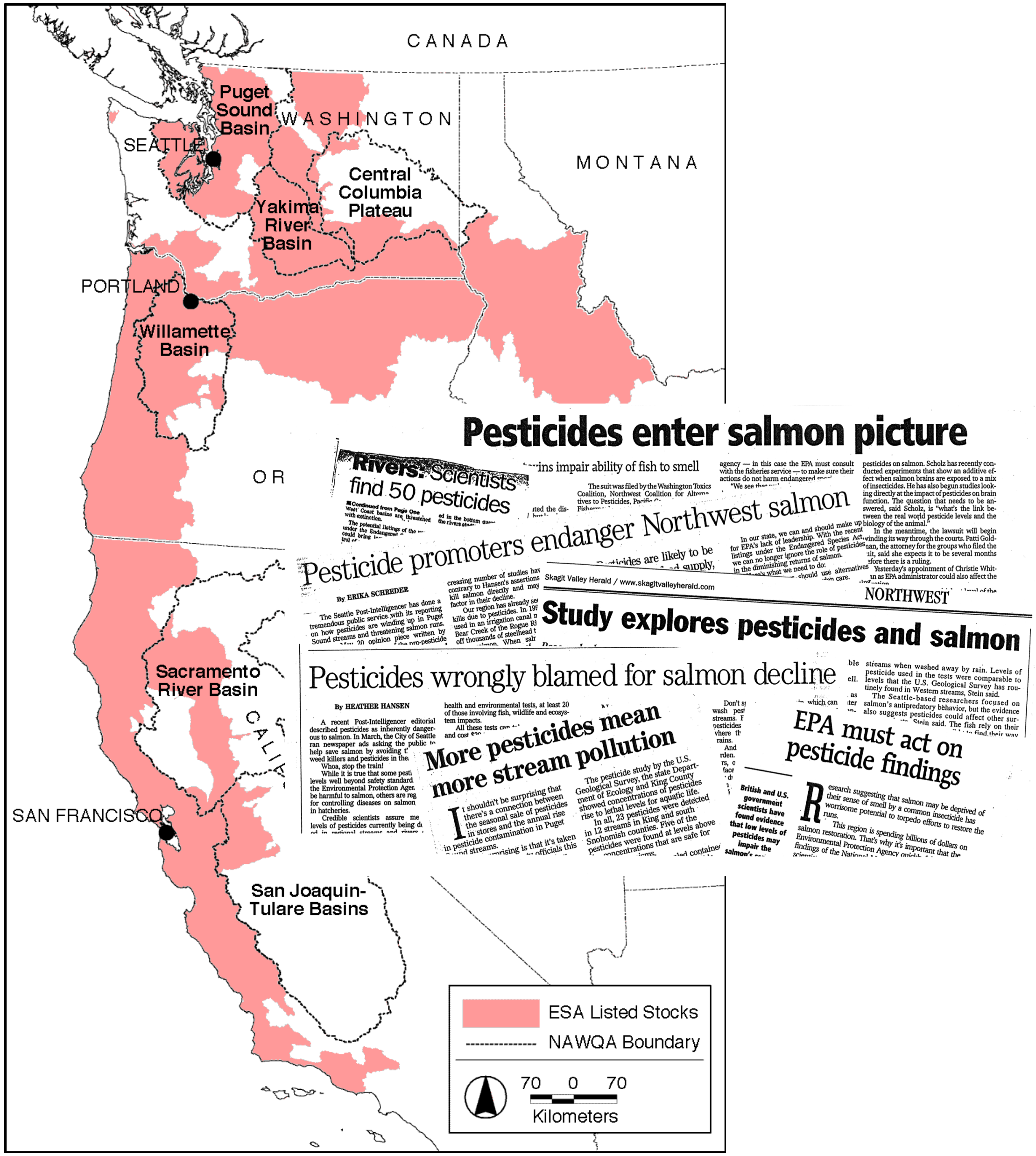
Synthesis and Communication

- ▶ Risk characterization and assessment
- ▶ Ecological modeling
- ▶ Resiliency forecasting
- ▶ Science communication
- ▶ Science-to-NOAA decisionmaking

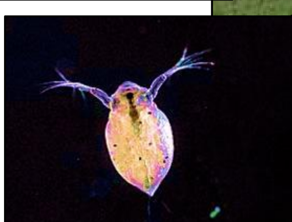
Guiding protected resource conservation

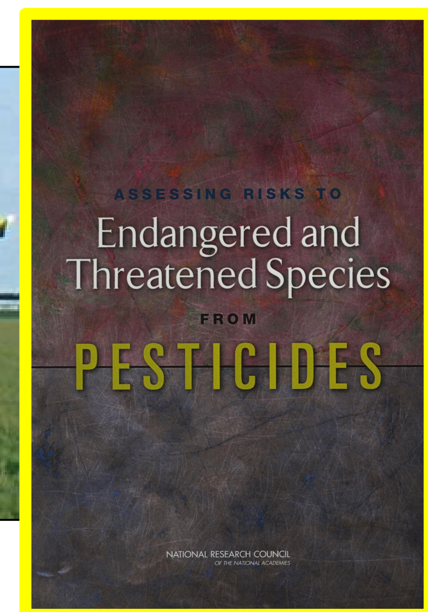
Case example: pesticides in west coast salmon habitats

- Sublethal effects?
- Mixture effects (e.g., synergism)?
- Interactions with other habitat stressors?
- Food web impacts?
- Population-scale effects?

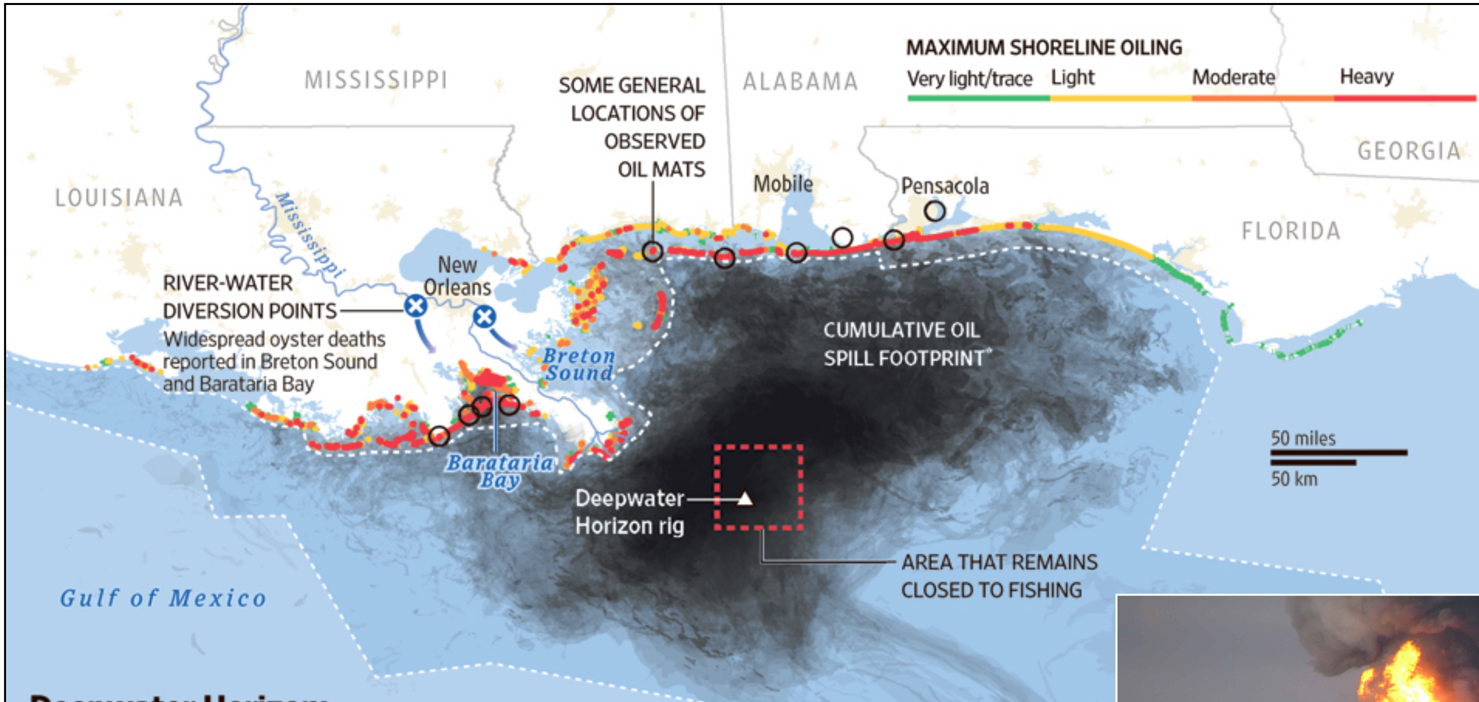


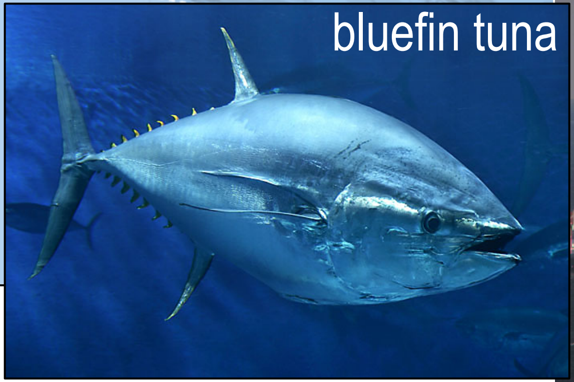
Litigation, research, and consultation timelines





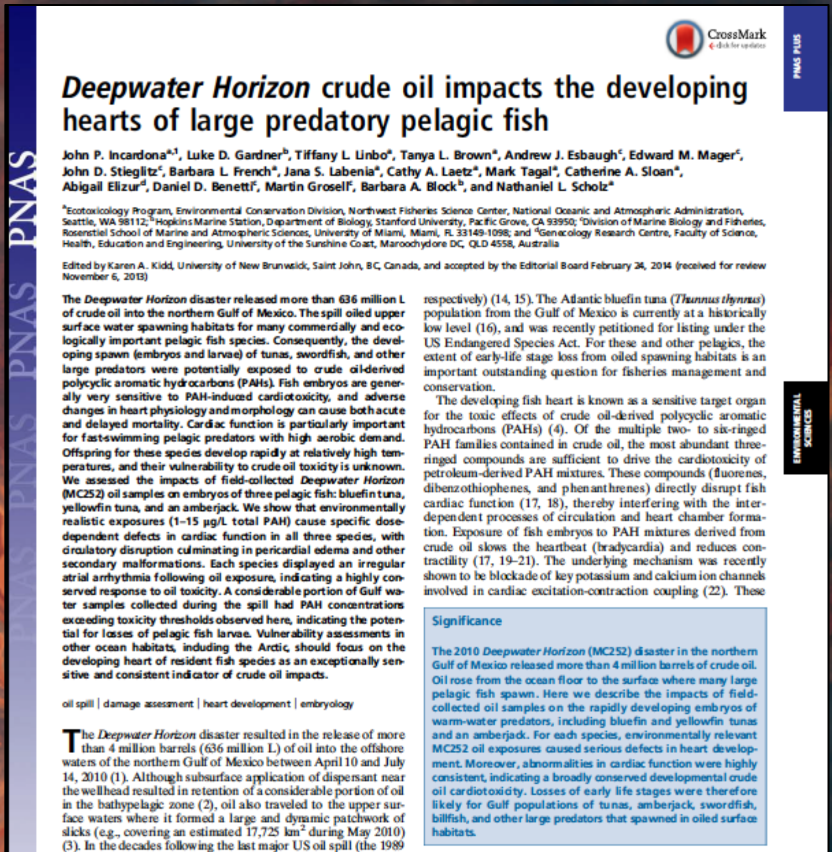
Case example: major disasters





Tuna Research & Conservation Center

Collaborative Facility (Stanford and Monterey Bay Aquarium)



PNAS PLUS

Deepwater Horizon crude oil impacts the developing hearts of large predatory pelagic fish

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Edited by Karen A. Kidd, University of New Brunswick, Saint John, BC, Canada, and accepted by the Editorial Board February 24, 2014 (received for review November 6, 2013)

The *Deepwater Horizon* disaster released more than 636 million L of crude oil into the northern Gulf of Mexico. The spill oiled upper surface water spawning habitats for many commercially and ecologically important pelagic fish species. Consequently, the developing spawn (embryos and larvae) of tunas, swordfish, and other large predators were potentially exposed to crude oil-derived polycyclic aromatic hydrocarbons (PAHs). Fish embryos are generally very sensitive to PAH-induced cardiotoxicity, and adverse changes in heart physiology and morphology can cause both acute and delayed mortality. Cardiac function is particularly important for fast-swimming pelagic predators with high aerobic demand. Offspring for these species develop rapidly at relatively high temperatures, and their vulnerability to crude oil toxicity is unknown. We assessed the impacts of field-collected *Deepwater Horizon* (MC252) oil samples on embryos of three pelagic fish: bluefin tuna, yellowfin tuna, and an amberjack. We show that environmentally realistic exposures (1–15 µg/L total PAH) cause specific dose-dependent defects in cardiac function in all three species, with circulatory disruption culminating in pericardial edema and other secondary malformations. Each species displayed an irregular atrial arrhythmia following oil exposure, indicating a highly conserved response to oil toxicity. A considerable portion of Gulf water samples collected during the spill had PAH concentrations exceeding toxicity thresholds observed here, indicating the potential for losses of pelagic fish larvae. Vulnerability assessments in other ocean habitats, including the Arctic, should focus on the developing heart of resident fish species as an exceptionally sensitive and consistent indicator of crude oil impacts.

oil spill | damage assessment | heart development | embryology

The *Deepwater Horizon* disaster resulted in the release of more than 4 million barrels (636 million L) of oil into the offshore waters of the northern Gulf of Mexico between April 10 and July 14, 2010 (1). Although subsurface application of dispersant near the wellhead resulted in retention of a considerable portion of oil in the bathypelagic zone (2), oil also traveled to the upper surface waters where it formed a large and dynamic patchwork of slicks (e.g., covering an estimated 17,725 km^2 during May 2010) (3). In the decades following the last major US oil spill (the 1989 *Exxon Valdez* spill
shown to be espec
The northern Gul
itats for a range
pelagic fish speci

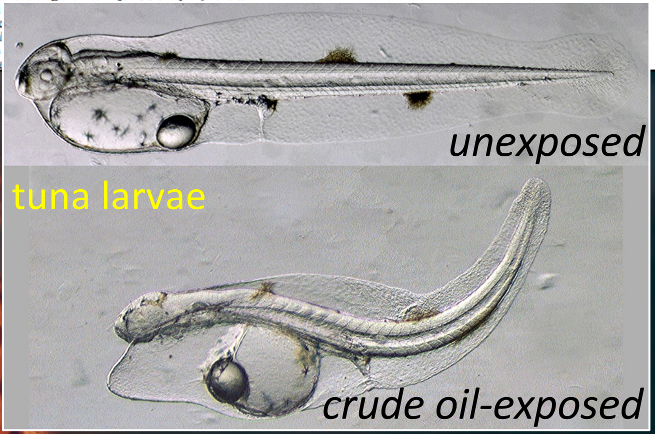
respectively) (14, 15). The Atlantic bluefin tuna (*Thunnus thynnus*) population from the Gulf of Mexico is currently at a historically low level (16), and was recently petitioned for listing under the US Endangered Species Act. For these and other pelagics, the extent of early-life stage loss from oiled spawning habitats is an important outstanding question for fisheries management and conservation.

The developing fish heart is known as a sensitive target organ for the toxic effects of crude oil-derived polycyclic aromatic hydrocarbons (PAHs) (4). Of the multiple two- to six-ringed PAH families contained in crude oil, the most abundant three-ringed compounds are sufficient to drive the cardiotoxicity of petroleum-derived PAH mixtures. These compounds (fluorenes, dibenzothiophenes, and phenanthrenes) directly disrupt fish cardiac function (17, 18), thereby interfering with the interdependent processes of circulation and heart chamber formation. Exposure of fish embryos to PAH mixtures derived from crude oil slows the heartbeat (bradycardia) and reduces contractility (17, 19–21). The underlying mechanism was recently shown to be blockade of key potassium and calcium ion channels involved in cardiac excitation-contraction coupling (22). These

Significance

The 2010 *Deepwater Horizon* (MC252) disaster in the northern Gulf of Mexico released more than 4 million barrels of crude oil. Oil rose from the ocean floor to the surface where many large pelagic fish spawn. Here we describe the impacts of field-collected oil samples on the rapidly developing embryos of warm-water predators, including bluefin and yellowfin tunas and an amberjack. For each species, environmentally relevant MC252 oil exposures caused serious defects in heart development. Moreover, abnormalities in cardiac function were highly consistent, indicating a broadly conserved developmental crude oil cardiotoxicity. Losses of early life stages were therefore likely for Gulf populations of tunas, amberjack, swordfish, billfish, and other large predators that spawned in oiled surface habitats.

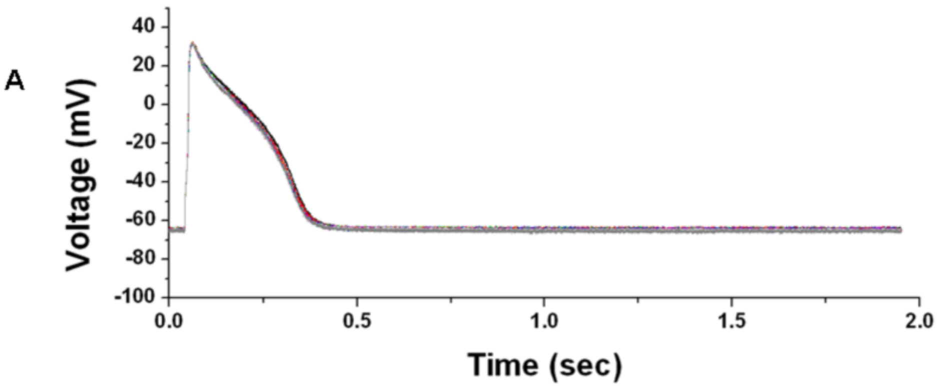
ENVIRONMENTAL SCIENCES



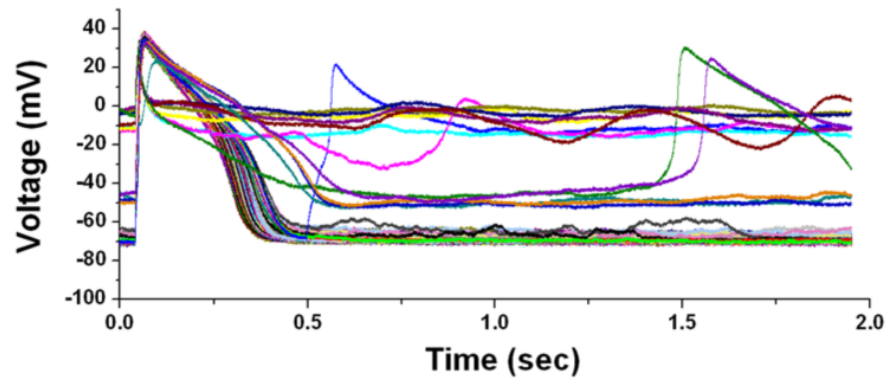
Deepwater Horizon surface oil, May 6, 2010 (photo by Daniel Beltrá)

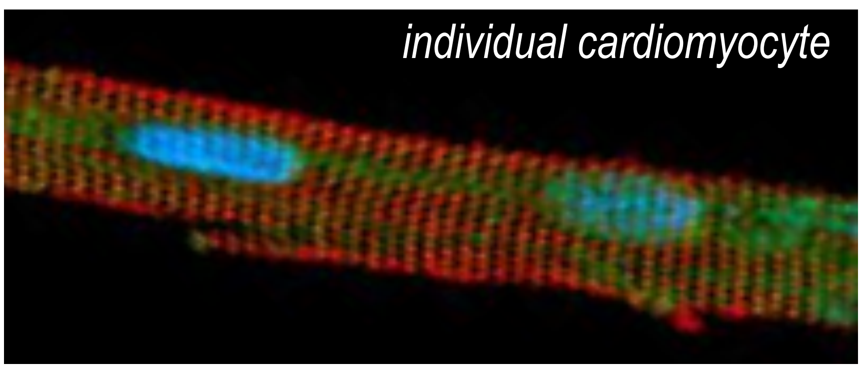
Crude oil disrupts tuna heart function

Normal tuna heart cell



Arrhythmia in response to crude oil





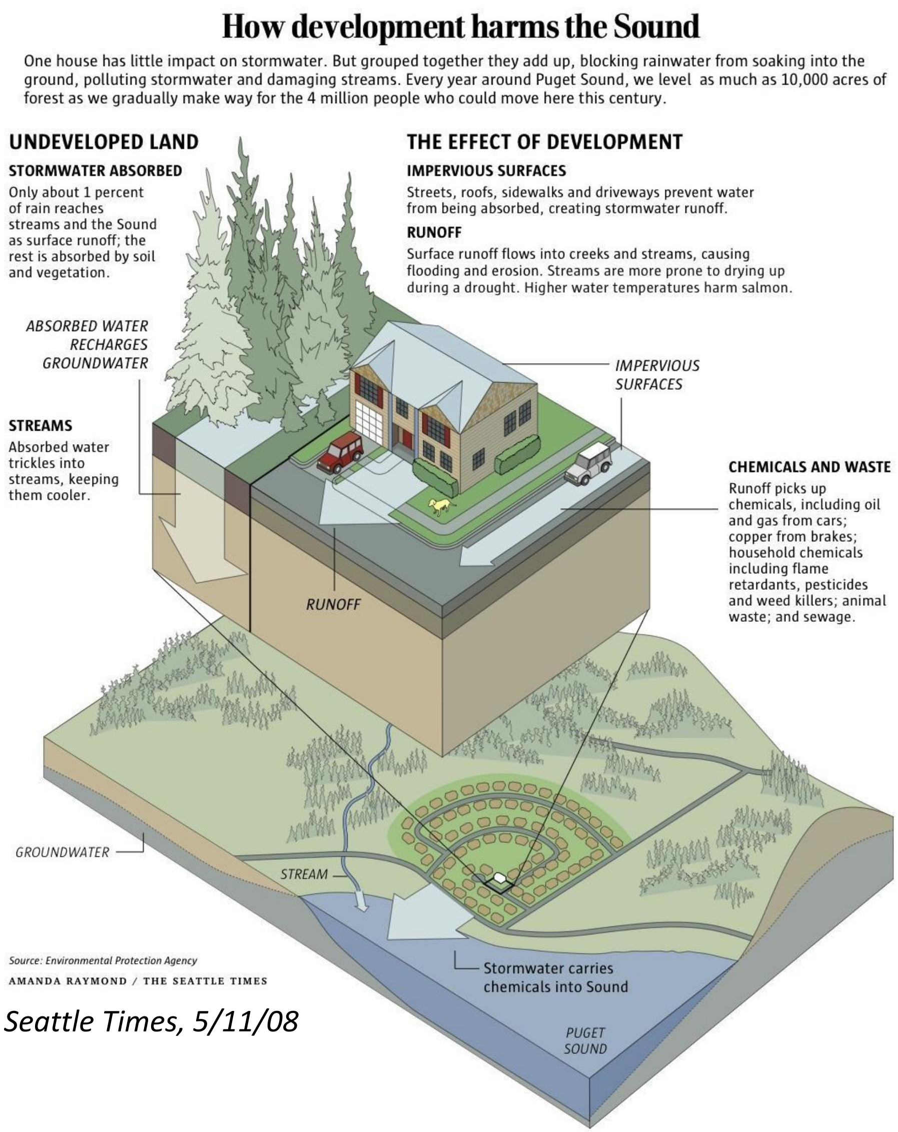
Science, 2014

Crude Oil Impairs Cardiac Excitation-Contraction Coupling in Fish

Fabien Brette,[1] Ben Machado,[1] Caroline Cros,[1] John P. Incardona,[2] Nathaniel L. Scholz,[2] Barbara A. Block[1]*

Crude oil is known to disrupt cardiac function in fish embryos. Large oil spills, such as the Deepwater Horizon (DWH) disaster that occurred in 2010 in the Gulf of Mexico, could severely

Case example: expanding stormwater threats



Seattle Times, 5/11/08

- *What are they?*
- *How can they be effectively minimized?*
- *Are ongoing efforts to reduce impacts working?*

Underwater video of an urban outfall

Time-lapse of a single storm event in Puget Sound (Alki Beach, West Seattle)

Combined sewer overflow, Montlake Cut

Urban runoff is killing coho spawners every year

More than a decade of spawner surveys in Puget Sound, losses often > 80% of an entire fall run

Initial findings and implications for listed coho

OPEN ACCESS Freely available online

PLoS one

Recurrent Die-Offs of Adult Coho Salmon Returning to Spawn in Puget Sound Lowland Urban Streams

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Estimating the Future Decline of Wild Coho Salmon Populations Resulting from Early Spawner Die-Offs in Urbanizing Watersheds of the Pacific Northwest, USA

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PLoS one

Landscape Ecotoxicology of Coho Salmon Spawner Mortality in Urban Streams

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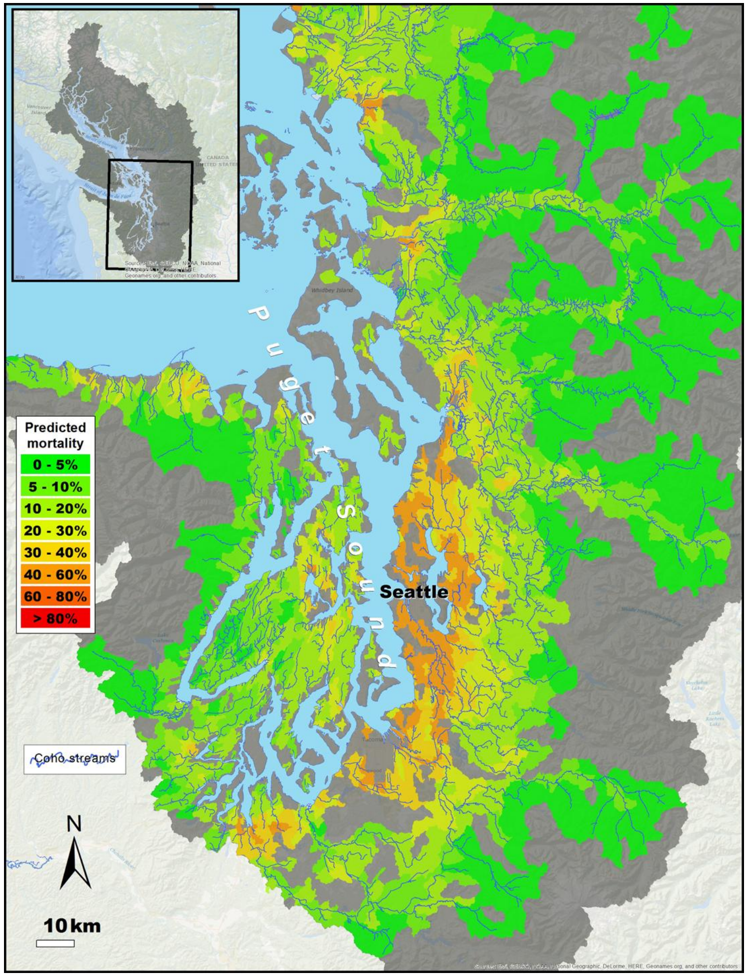
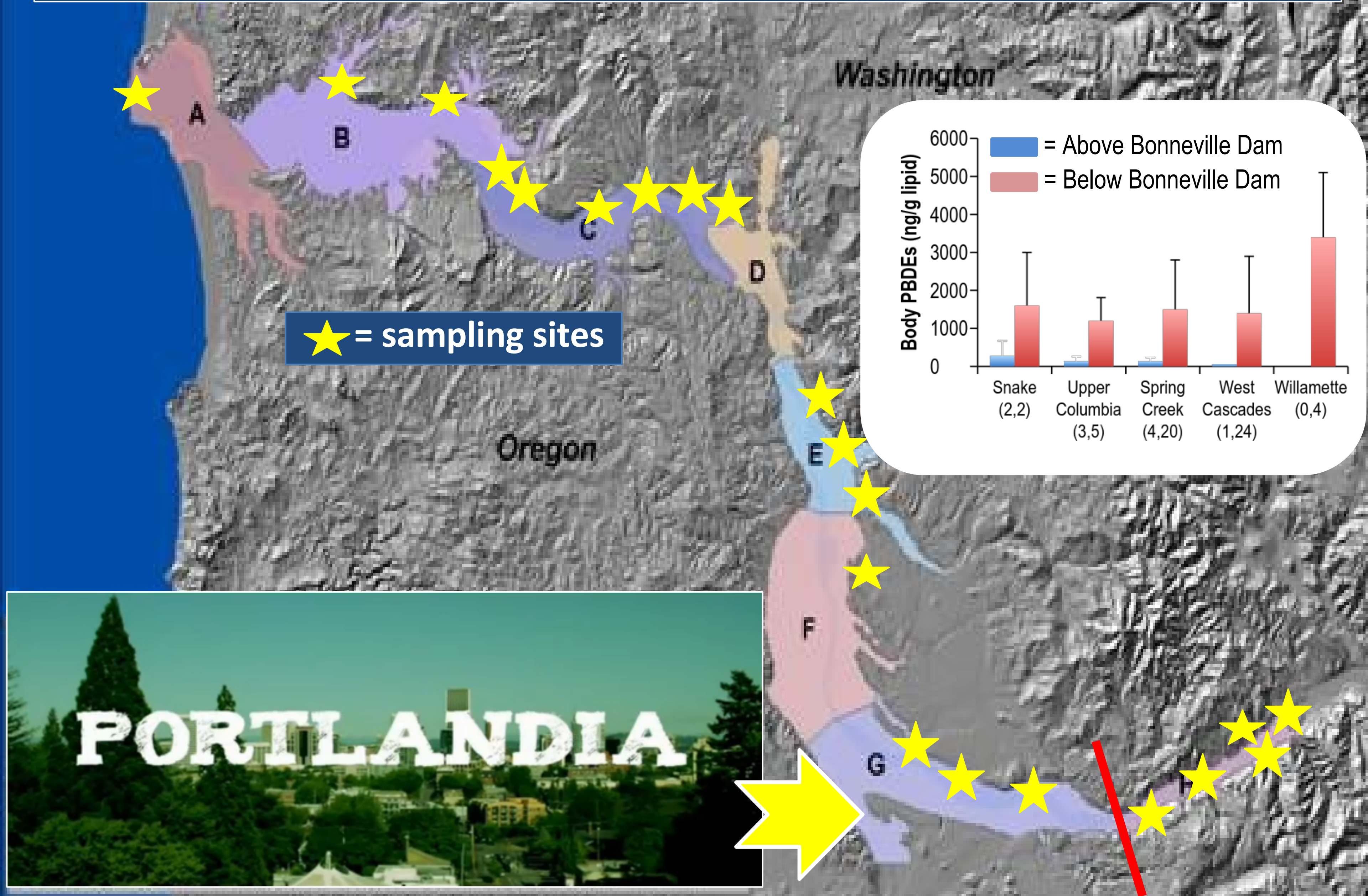
Refined predictive forecasting



ESA-listed salmon: a toxic seaward migration



Key future challenges

- The laboratory platform for environmental health research (e.g., ‘omics, informatics) is evolving more rapidly than most other NMFS science areas
- NMFS science funding for toxics and protective resources is predominately reactive; proactive planning for emerging habitat threats is needed
- There is no national-level strategy, or even coordination among FMCs, on NMFS science specific to ocean pollution, listed species, and their habitats
- Future demographic trends are clear; coastal watersheds/estuaries will be increasingly impacted by toxics, particularly from non-point source pollution
- Much more work is needed to connect the dots between health impacts at the scale of individual fish and ecosystem-based management